Assessment of Mechanical Pain Thresholds in the Orofacial Region: A Comparison Between Pinprick Stimulators and Electronic Von Frey Device

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Aims: To compare mechanical pain thresholds (MPTs) in the orofacial region assessed with two different approaches: with an electronic von Frey (EvF) device and with custom-made weighted pinprick stimulators. The test-retest reliability, variability of MPTs, and time duration of each test were also compared, as well as the ability of each test to create stimulus-response (S-R) curves. **Methods:** A total of 16 healthy volunteers participated. The MPT and S-R curve measurements were done with the two different techniques at three sites: on the skin of the right cheek (face), on the buccal gingival mucosa of the right upper premolar region (gingiva), and on the tip of the tongue (tongue). The same protocol was repeated 1 to 2 weeks later to determine test-retest reliability. **Results:** The MPT measurements with the EvF device were significantly faster (74.4 ± 20.8 seconds) than those with the pinprick stimulators (196.1 ± 33.0 seconds; $P < .001$). The absolute MPT values obtained with the EvF device were significantly higher than the values obtained with the pinprick stimulators at all test sites ($P < .001$). MPTs assessed with the EvF device showed higher reliability (intraclass correlation coefficient [ICC] = 0.77–0.94) than MPTs assessed with the pinprick stimulators (ICC = 0.57–0.84; $P = .041$). The reliability of the S-R curves was excellent for both methods with no significant differences between the methods ($P = .403$). **Conclusion:** This study indicates that MPTs tested in the orofacial region with the EvF device were significantly higher than MPTs tested with the pinprick stimulators. However, the EvF device can be used with higher reliability and less time consumption for assessment of MPTs in the orofacial region than the pinprick stimulator technique, and also allows comparable construction of S-R curves. *J Oral Facial Pain Headache 2016;30:338–345. doi: 10.11607/ofph.1641*

Key words: *orofacial pain, quantitative sensory testing, reliability, somatosensory testing, variability*

Quantitative sensory testing (QST) is a widely accepted tool for somatosensory testing and examination of pain patients.[1–8] The German Research Network for Neuropathic Pain (DFNS) has proposed a comprehensive QST protocol that includes a total of 13 parameters based on 7 tests that assess somatosensory functions evoked by Aδ-, Aβ-, and C-fiber activation.[2] The QST test battery has been subsequently modified for the orofacial region[1,4,7,9] and the reliability of the QST test battery has been found to be acceptable.[4,6] However, the clinical application of the full QST test battery is limited by the time-consuming nature of the examination and the need for highly trained and calibrated examiners.[3]

Several different psychophysical techniques have been proposed and used in the description of orofacial somatosensory function.[10–14] For pinprick pain, von Frey filaments or force-calibrated pins can be used for the quantitative determination of the pain detection threshold.[1] As in the DFNS protocol, determination of the mechanical pain threshold (MPT) may be performed with weighted pinprick stimuli delivered with a custom-made set of seven stimulators.[2] Another approach to determine MPT is to use an electronic von Frey device (eg, EvF, SENSEbox, Somedic), which is able to assess somatosensory functions related to

Aδ- and C-fiber activation, including pinprick pain thresholds.[15,16] The pinprick pain threshold may be determined with the EvF device by having the subject push a response button as soon as he or she feels the slightest painful sensation, in much the same way that pressure pain thresholds are determined with an algometer.[15,16] It can be speculated that the continuous stimulation caused by an EvF device, in comparison with the discrete stimulation in an ascending-descending psychophysical technique that uses weighted pinprick stimulators, may *(1)* result in different absolute MPT values, *(2)* be less time consuming, and *(3)* differ in regard to reliability.

Therefore, the first aim of this study was to compare the MPTs in the orofacial region assessed with an EvF device to the MPTs assessed with weighted pinprick stimulators. The test-retest reliability, variability of MPTs, and time duration of each test were also compared, as well as the ability of each test to create stimulus-response (S-R) curves. The following hypotheses were tested: *(1)* the MPT values measured by the EvF device are different than MPT values measured by the weighted pinprick stimulators; *(2)* the EvF device can be used to determine MPTs and S-R curves faster than using weighted pinprick stimulators; and *(3)* the EvF device has similar or better reliability values for MPTs and S-R curves than pinprick stimulators.

Materials and Methods

Participants

Healthy participants in this study were recruited from Aarhus University students and staff. Questionnaire-based exclusion criteria were: ongoing pain, chronic pain during the last 6 months, systemic diseases (eg, metabolic diseases, neurogenic diseases, or cardiovascular disorders), previous radiotherapy or chemotherapy, intake of any medicine affecting the nervous system in the last week, and functional or behavioral disorders (eg, fibromyalgia syndrome or psychogenic illnesses). A total of 16 healthy participants (9 male, 7 female; mean [± standard deviation (SD)] age 28.0 ± 6.2 years, range 21–44 years) were recruited for this paired study design. The sample size was determined based on previous QST studies[15] using the EvF device and weighted pinprick stimulator techniques. All participants gave written informed consent and the study was performed in accordance with the Helsinki Declaration II.

Study Design

The measurements were done at three orofacial test sites: the skin of the right cheek (face), the gingival mucosa of the right upper premolar region (gingiva), and the tip of the tongue (tongue). The test sites were the same as in the QST study by Pigg et al.[4] The MPTs of the participants were tested using two different methods: *(1)* Custom-made weighted pinprick stimulators (Aarhus University) and *(2)* an EvF device (EvF, SENSEbox, Somedic), which is a computer-controlled device with SENSEbox software that can measure thresholds and is also able to deliver fixed stimuli with visual feedback from a computer screen.

S-R curves were built using the same two devices. Figure 1 shows the experimental protocol of the study. First, MPTs at the three test sites were measured by use of the weighted pinprick stimulators. Next, MPTs at the three test sites were measured by use of the EvF device. Finally, S-R curves were built for all three sites at which both devices were used. The time duration to perform each measurement (in seconds) was recorded by the examiner. All measurements were repeated in the exact same manner in a second session by the same examiner 1 to 2 weeks after the first session.

Assessment of MPTs

The weighted pinprick stimuli were delivered with a custom-made set of seven stimulators. Each stimulator had a flat contact surface of 0.2-mm diameter. The stimulators exerted the following forces: 8 mN, 16 mN, 32 mN, 64 mN, 128 mN, 256 mN, and 512 mN.[17–19] The participants were stimulated for about 2 seconds during each measurement with the help of an electronic metronome. The measurement of the MPT was performed using a modified method of limits.[3] The MPT was the geometric mean of five series of seven ascending and descending stimulus intensities (Fig 1a).

The EvF device was used to determine the MPT as follows: participants were asked to push the response button as soon as they felt the slightest sensation of pain.[15,16] The rate of increase in pressure was 98 mN/s.[15] The measurement was repeated five times at each test site. The MPT was calculated as the mean of the five values (Fig 1b).

S-R Curves

The same weighted pinprick devices used for the MPT measurements were also used for building S-R curves. At each test site, five series of pinprick stimuli were applied, with each series containing seven different force levels applied in randomized order with interstimulus intervals of 10 seconds. For each of the resulting 35 stimuli, the participants were asked to rate the stimulus-evoked pain on a 0–100 numeric rating scale (NRS) with the endpoints 0 indicating "no pain" and 100 indicating "most intense pain imaginable" (Fig 1c).

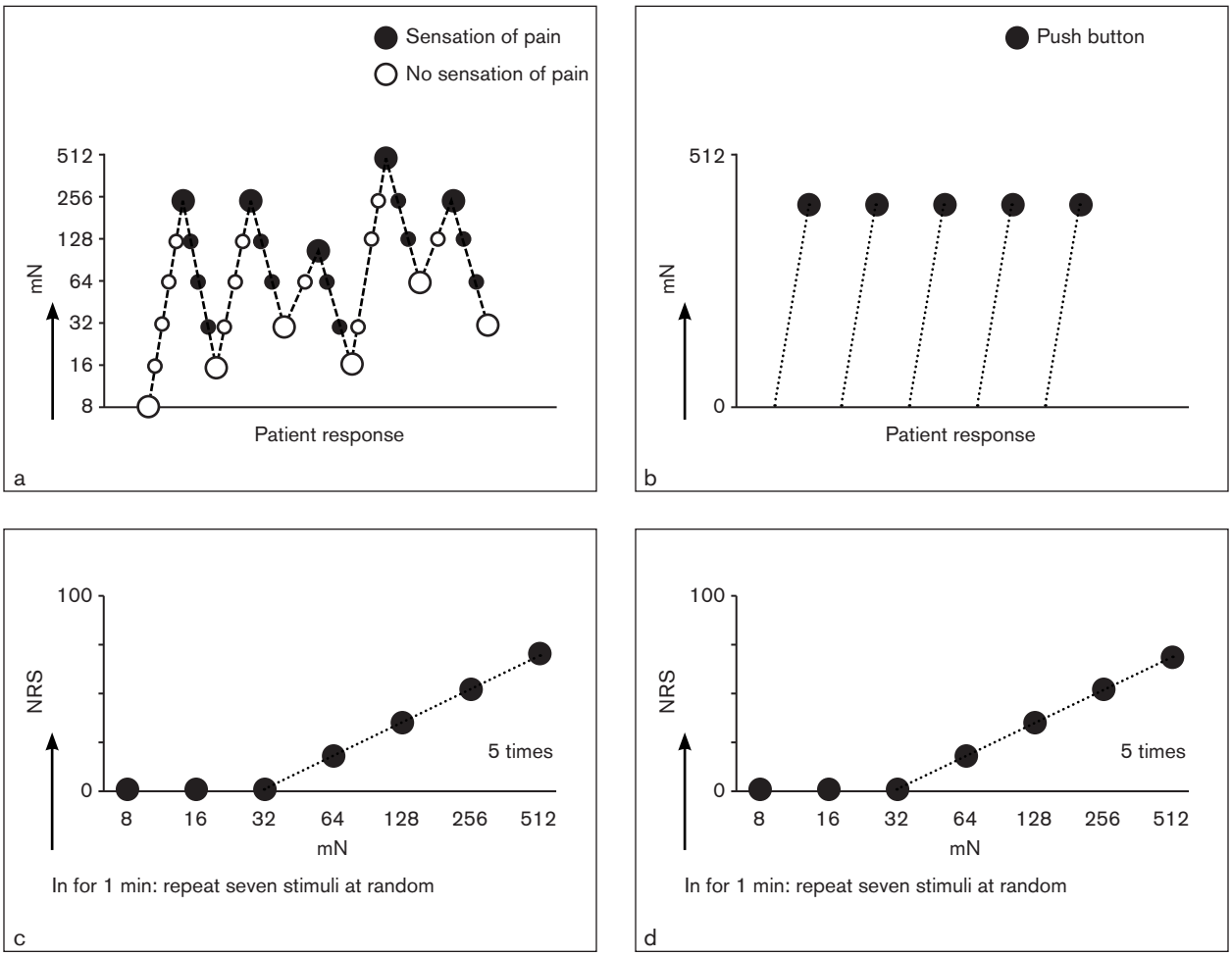


Fig 1 Protocol of the test. **(a)** Determination of MPTs with the use of custom-made weighted pinprick stimulators. **(b)** Determination of MPTs with the use of the electronic von Frey (EvF) device. **(c)** S-R curves built with the use of pinprick stimulators. **(d)** S-R curves built with the use of the EvF device. Three sites were tested: the skin of the right cheek (face), the buccal gingival mucosa of the right upper premolar region (gingiva), and the tip of the tongue (tongue). Arrows indicate that 1 minute before the first stimulation, verbal instructions were given to the participants. NRS = numeric rating scale, 0–100.

The EvF device was then used to target the same force levels as provided with the mechanical pinprick stimulators. A series of seven measurements (each measurement with one of the seven stimulus intensities noted above) was made five times. The examiner controlled the EvF device and made the fixed stimuli by using visual feedback from the computer to collect the data for S-R curves, which were generated by use of the EvF device. The target levels of the EvF device were 8 mN, 16 mN, 32 mN, 64 mN, 128 mN, 256 mN, and 512 mN. The participants were stimulated for about 2 seconds during each measurement with the help of an electronic metronome. The participants rated each stimulus-evoked pain on the same 0–100 NRS noted above (Fig 1d).

Statistical Analyses

The time duration to perform each MPT measurement and to collect data for each S-R curve, the NRS scores of each force (8, 16, 32, 64, 128, 256, and 512 mN) during the building of each S-R curve, and the means and standard deviations (SDs) were calculated. The MPTs and the time duration were analyzed by using gender as an independent factor and sites, methods (pinprick stimulators and EvF device), and sessions as dependent factors in a four-way analysis of variance (ANOVA). NRS scores of each force from building S-R curves were compared between genders (independent factor) and between sites, methods (pinprick stimulators and EvF device), sessions, and forces (8, 16, 32, 64, 128, 256, and 512 mN) as dependent factors in a five-way ANOVA.

In order to determine the best fit of the S-R curves, linear, exponential, and logarithmic regression lines were applied to each individual S-R curve.[20] A value of 0.1 was added to the 0 values for the exponential fits. The coefficients of determination (CD; r^2) from the different regression lines were compared between genders (independent factor) and between lines (linear, exponential, and logarithmic), sites, methods, and sessions as dependent factors by using a five-way ANOVA.

All post hoc comparisons were performed by using Tukey post hoc test with correction for multiple comparisons.

Intraexaminer reliability was estimated using intraclass correlation coefficients (ICCs) for the MPTs and slopes of the linear regression lines of the S-R curves.[4] The ICC values were calculated by using a two-way random-effects model. ICCs less than or equal to 0.20 were considered poor agreement; 0.21–0.40 fair; 0.41–0.60 moderate; 0.61–0.80 good; and 0.81–1.00 excellent.[21] The ICCs were compared between the two stimulation methods by using a paired *t* test.

For each individual MPT, the individual coefficient of variation (CV) was determined as the ratio of the SD to the mean of the five intensities that elicited pain (a "yes" response) and to the mean of the five intensities that did not elicit pain (a "no" response) in the ascending-descending protocol for the pinprick stimulators, or to the mean of the five intensities that caused participants to push the button for the EvF device.[22] CV values for the five "yes" responses and the five "no" responses of the MPTs tested with the pinprick stimulators were calculated separately as "MPT-Y" and "MPT-N." The CV values were calculated for both methods for all three test sites. A smaller CV indicates a more consistent threshold measure.[22] The CV values were calculated the same way as in a previous study by Yang et al.[22] Differences in CV values between genders (as an independent factor) and sites, methods (MPT-Y, MPT-N, and MPT-EvF), and sessions (as dependent factors) were analyzed using a four-way ANOVA. Post hoc comparisons were estimated using Tukey post hoc test with correction for multiple comparisons.

The STATISTICA software (StatSoft) was used for all analyses. For all tests, *P* values less than .05 were considered to be statistically significant.

Table 1 Mean Values and Standard Deviations (SDs) for Mechanical Pain Thresholds (MPTs)

	Pinprick stimulators			EvF		
Test sites	Face	Gingiva	Tongue	Face	Gingiva	Tongue
Mean (mN)	100.8	134.5	45.0	356.2	357.7	203.4
SD	86.3	110.3	25.2	150.2	169.0	81.7

MPTs tested at three sites: Face = the skin of the right cheek; Gingiva = the buccal gingival mucosa of the right upper premolar region; Tongue = the tip of the tongue.

Table 2 Intraexaminer Reliability for Mechanical Pain Thresholds (MPTs) and Stimulus-Response (S-R) Curves

	Pinprick stimulators				EvF			
Test sites	Face	Gingiva	Tongue	Total	Face	Gingiva	Tongue	Total
MPTs	0.57	0.84	0.60	0.79	0.91	0.94	0.77	0.93
S-R curves	0.84	0.87	0.90	0.88	0.78	0.91	0.79	0.83

The intraclass correlation coefficients (ICCs) for intraexaminer reliability are shown for MPTs and slopes of the best fitted straight lines for S-R curves obtained with pinprick stimulators and EvF device for the three test sites. Face = the skin of the right cheek; Gingiva = the buccal gingival mucosa of the right upper premolar region; Tongue= the tip of the tongue.

Results

All 16 participants completed the study without side effects or complications (eg, no bleeding or trauma on oral mucosa/skin sites).

MPTs

Table 1 lists the mean values and SDs for all MPT measurements at the three test sites. Regarding the results of the four-way ANOVA on MPTs, there were significant differences among methods and test sites ($P < .001$). There were no significant effects of other factors (gender and session; all $P > .336$). MPTs assessed with EvF were significantly higher than those assessed with a pinprick stimulator (post hoc test: $P < .001$), and the MPTs for the tongue assessed by both methods were significantly lower than for other sites (face and gingiva; post hoc test: $P < .001$). In addition, there was a significant method × site interaction for MPTs ($P < .001$). The post hoc test of this interaction again demonstrated higher MPTs for EvF compared with pinprick stimulators at all sites (post hoc test: $P < .001$) and showed lower MPTs on the tongue assessed by both methods than on other sites (face and gingiva; post hoc test: $P < .001$).

Table 2 lists the ICC values for intraexaminer reliability for all MPT estimates. All ICC values were in the good to excellent range, except for MPTs assessed by pinprick stimulators on the face and tongue, which were in the moderate range. The EvF device showed significantly higher ICCs than did the pinprick stimulators (paired *t* test: $P = .041$).

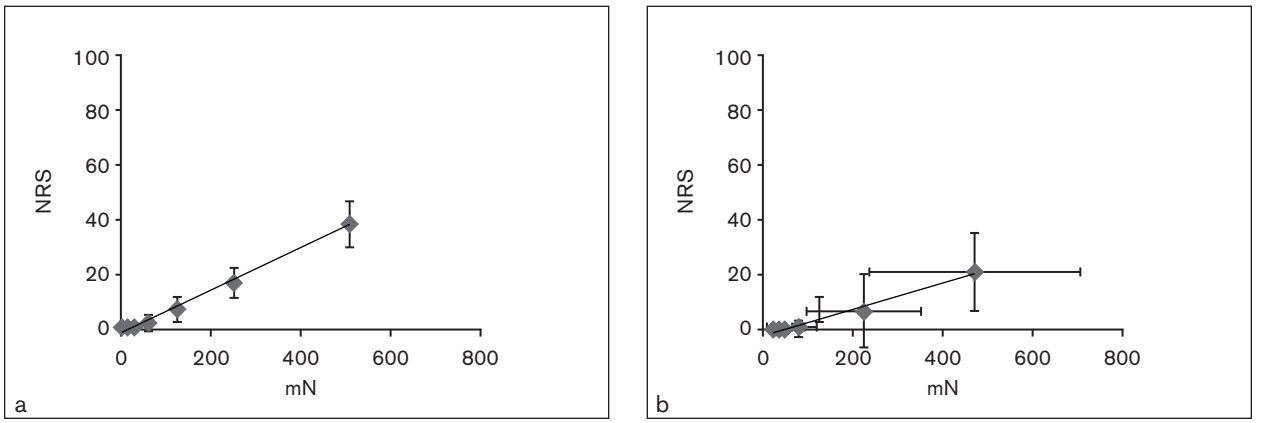


Fig 2 Examples of typical S-R curves obtained with custom-made weighted **(a)** pinprick stimulators and **(b)** EvF device in this study. NRS = numeric rating scale, 0–100. Mean ± SD values are shown.

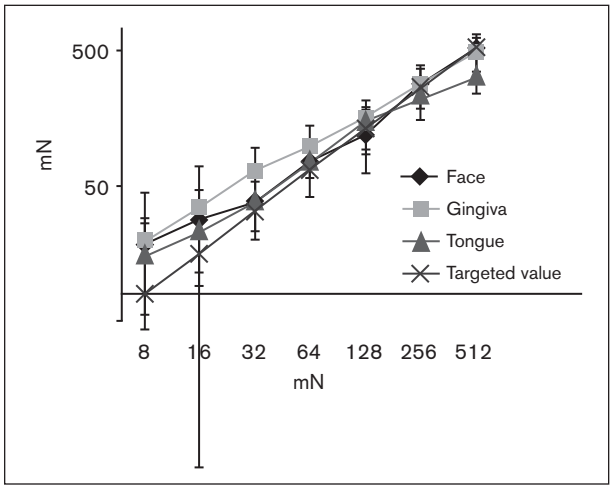


Fig 3 Actual values for each targeted value with EvF device. Targeted values were 8 mN, 16 mN, 32 mN, 64 mN, 128 mN, 256 mN, and 512 mN for the three test sites (face = the skin of the right cheek; gingiva = the buccal gingival mucosa of the right upper premolar region; and tongue = the tip of the tongue). Mean ± SD values are shown.

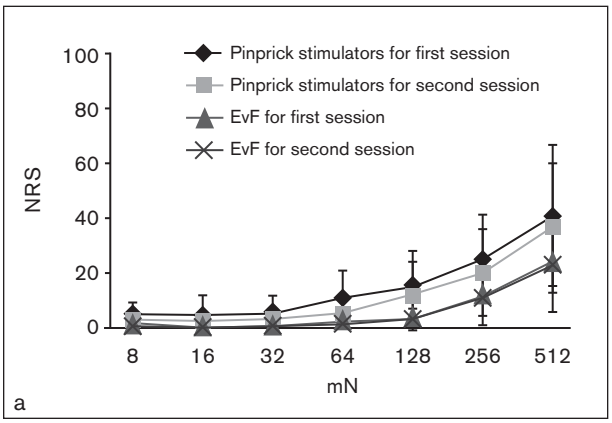
The means of individual CV values were MPT-Y: 0.39 ± 0.27, MPT-N: 0.37 ± 0.28, MPT-EvF: 0.22 ± 0.09 for the face; MPT-Y: 0.40 ± 0.29, MPT-N: 0.42 ± 0.24, and MPT-EvF: 0.22 ± 0.10 for the gingiva; and MPT-Y: 0.37 ± 0.19, MPT-N: 0.40 ± 0.15, and MPT-EvF: 0.22 ± 0.09 for the tongue. For the CV values, there were significant differences between methods, with significantly lower CV values for MPT-EvF than for MPT-Y and MPT-N (post hoc test: $P < .001$). There were no significant effects of any other factor (gender, site, and session; all $P > .189$) and there were no significant interactions between factors ($P > .290$).

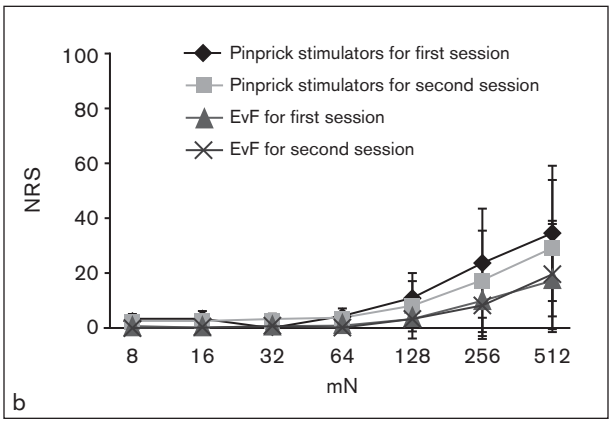
S-R Curves

The averages of the CD values were 0.90 ± 0.09, 0.73 ± 0.15, 0.72 ± 0.13 for the linear, exponential, and logarithmic regression lines, respectively, when fitted to the S-R curves. The ANOVAs indicated that there were significant differences among regression lines, sites, and methods ($P < .025$). There were no significant effects of the other factors (gender and session; all $P > .164$). The post hoc results indicated that the linear regression lines had higher (ie, better) CD values than the exponential and logarithmic regression lines ($P < .001$), the face had higher CD values than the gingiva ($P = .019$), and the second session had higher CD values than the first session ($P < .001$). In addition, there were significant line × site, line × method, and line × session interactions for the CD values ($P < .001$), with the linear regression lines consistently having higher CD values than the exponential and logarithmic lines (post hoc test: $P < .001$). Figure 2 is an example of a typical linear regression line fitted to the S-R curve in this study. The slope of the linear regression line was determined and used for reliability evaluation. Table 2 lists the ICC values for intraexaminer reliability for MPTs and for the slope of the line. There were no significant differences in ICC values between EvF slopes and slopes generated by the pinprick stimulators (paired *t* test: $P = .403$).

Figure 3 shows the means of actual values for each targeted value tested with the EvF device on the face, gingiva, and tongue. The means ± SDs of total actual EvF values for all sites were 18.2 ± 16.8 mN, 28.8 ± 24.1 mN, 46.7 ± 25.6 mN, 80.7 ± 36.8 mN, 135.4 ± 59.3 mN, 254.0 ± 97.5 mN, and 431.9 ± 152.1 mN for targeted values of 8 mN, 16 mN, 32 mN, 64 mN, 128 mN, 256 mN, and 512 mN, respectively.

Figure 4 shows the results of NRS scores for each force, displayed as S-R curves. For the NRS scores, there were significant differences among sites, methods, and force levels ($P < .001$), but no significant differences among gender and session





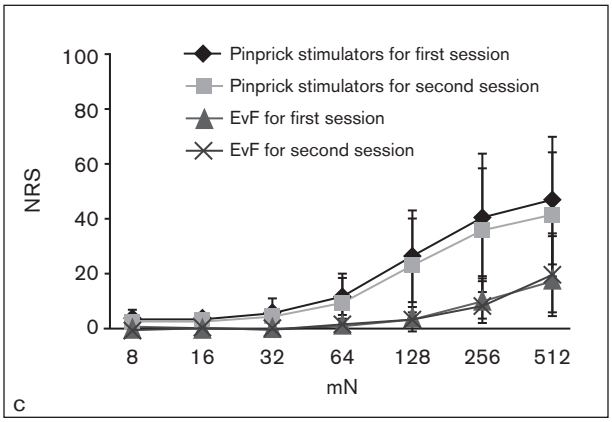


Fig 4 The means of NRS scores for the **(a)** face, **(b)** gingiva, and **(c)** tongue were generated by the two methods in two sessions and were used to build S-R curves. For EvF, the targeted EvF values (8, 16, 32, 64, 128, 256, and 512 mN) were used for the x-axis.

(P > .166). The NRS scores for the tongue were significantly higher than those for the gingiva (post hoc test: P < .004). The pinprick stimulators showed higher NRS scores than the EvF device (post hoc test: P < .001). For the force level results, the NRS scores increased with increasing force levels from 128 mN to 512 mN (post hoc test: P < .004); however, there were no significant differences in NRS scores between force levels in the range of 8 mN to 128 mN (post hoc test: P > .240).

Duration of Measurements

Figure 5 shows the time needed for each measurement. The average measurement times for MPT determination at all sites were 196.1 ± 33.0 seconds for the pinprick stimulators and 74.4 ± 20.8 seconds for the EvF device. For the time duration of MPT measurement, there were significant differences among methods, sites, and sessions (P < .001). There were no significant effects of gender (P > .095). The EvF device took a shorter time to perform each MPT determination than the pinprick stimulators (post hoc test: P < .001). The measurement on the face took a shorter time than on the gingiva, and a longer time than on the tongue (post hoc test: P < .001) with both methods. The duration was longer with both methods during the first session compared with the second session (post hoc test: P < .001). In addition, there was a significant method × site interaction for the time duration of MPT assessment (P < .001), and the post hoc test of this interaction demonstrated pinprick stimulator testing on the face taking a shorter time than on the gingiva and a longer time than on the tongue (post hoc test: P < .009). EvF testing showed no significant duration differences between sites (post hoc test: P > .311).

The average measurement time of all sites for building S-R curves was 395 ± 43 seconds for the pinprick stimulators and 342 ± 47 seconds for the EvF device. For the time duration to build S-R curves, there were significant differences between methods, sites, and sessions (P < .003). There were no significant effects of gender (P > .175) and no significant interactions between factors (P > .067). The time needed to build S-R curves by using the EvF device was shorter than that with the pinprick stimulators (post hoc test: P < .001). The time needed to build S-R curves on the face was shorter than on the gingiva and longer than on the tongue (post hoc test: P < .001) with both methods. The time needed to build S-R curves was longer in the first session than in the second session (post hoc test: P < .003) with both methods.

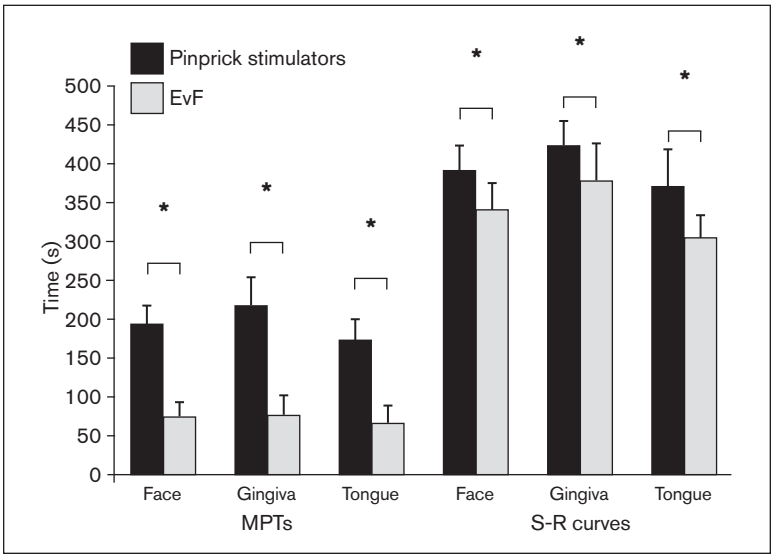


Fig 5 Duration of measurements. Means ± standard deviations (SDs) of the time needed to assess the MPTs and S-R curves with the use of pinprick stimulators and EvF device for the three anatomical sites (face = the skin of the right cheek; gingiva = the buccal gingival mucosa of the right upper premolar region; and tongue = the tip of the tongue). **P* values lower than .05 were considered to be statistically significant.

Discussion

MPTs

MPTs tested with the EvF device were significantly higher than those tested with the pinprick stimulators. The two methods differ with regard to probe design, mode of application (discrete stimuli vs continuous stimuli), and psychophysical protocol; and the main reason for the differences between the MPTs may, indeed, be the technique for determining the thresholds.[1] The MPTs with the pinprick stimulators are calculated as the geometric mean of five series of seven ascending and descending stimulus intensities.[1] In contrast, the EvF measurement is based on an increasing stimulus intensity, where the participant is instructed to push the button to signal his or her perception of the sensation of interest; ie, the pain threshold.[15,16]

The MPTs determined with the pinprick stimulators in the present study are similar to those reported by Pigg et al at the same orofacial test sites.[4] The MPTs on the skin of the cheek were lower than those on the gingiva and higher than the thresholds on the tongue, which is also in accordance with the Pigg et al study.[4] The MPTs measured with the EvF device in the present study showed a similar pattern of higher thresholds than the pinprick stimulators between sites.

This study was, according to the authors' knowledge, the first to evaluate the intraexaminer reliability of the EvF device and to compare it with that of the pinprick stimulators. Overall, the EvF method had better reliability (significantly higher ICC values) than did the pinprick stimulators. The intraexaminer reliability of the weighted pinprick stimulators was also similar to a previous study testing identical sites.[4]

The present study also evaluated the variability of the single, individual measures of MPTs and compared CVs between the EvF device and the pinprick stimulators. The CV values obtained with the EvF device were significantly lower than those with the pinprick stimulators, which indicates that EvF measurements are more consistent than pinprick stimulator measurements.[1] CVs of MPTs obtained with the use of the pinprick stimulators were also reported by Yang et al[22] who tested three sites: the infraorbital region, the mental region, and the dorsum of the hand. They showed that the variability for MPT-Y and MPT-N on the dorsum of the hand was significantly higher than in the facial regions.[22] In the present study, there were no significant differences between the orofacial test sites.

S-R Curves

The duration of time to build S-R curves with the EvF device was only slightly shorter than with the pinprick stimulators, and the two techniques showed similar intraexaminer reliability. However, there were significant differences between NRS scores from building S-R curves with the pinprick stimulators and those of the EvF device. It can be considered a limitation that building S-R curves by using the EvF device is demanding for the examiner, who must control the applied force manually while looking at the computer screen. The EvF device is designed to be used with visual feedback provided directly on the EvF handpiece by means of colored diodes to indicate whether the rate of increase in force is correct. Thus, to read the actual force on the computer screen, the examiner must lift his/her eye from the handpiece. Figure 4 shows the actual EvF value for each targeted value. All lines seem to be in accordance with the target or slightly above the target, except for the tongue site for the highest targeted value (512 mN). This may be explained by the physical properties of the tongue, where it proved difficult to obtain the highest force levels applied to the resilient soft tissue with the EvF device. Nevertheless, the present study suggested that it may be feasible to use the EvF device to establish S-R curves in the orofacial region.

Duration of Measurements

In the present study, the EvF measurements took less than half of the time needed to perform MPT measurements with the pinprick stimulators. This is probably related to the number of discrete stimulations needed to perform the individual tests with the use of the pinprick stimulators. Only five stimulations were used to measure the MPT by using the EvF device, but multiple stimuli were needed for one MPT measurement with the use of the pinprick stimulators. Outside of hospital and university clinics, QST is limited partly due to the time-consuming nature of the examination.[1,23] Therefore, the EvF device could help save time without sacrificing measurement reliability.

In the case of the time duration of building S-R curves, the EvF S-R curve was more quickly established than the S-R curve derived from the pinprick stimulators. This could have been due to the examiner having to change the stimulator between each stimulus for the weighted pinprick stimulator measurement; this is not needed when the EvF device is used.

In conclusion, this methodologic study has indicated that MPTs tested with the EvF are significantly higher than values obtained with pinprick stimulators. However, EvF can be used to assess MPTs in the orofacial region with higher reliability, less variability, and less time consumption than with the presently recommended pinprick stimulator technique according to the DFNS protocol.

Acknowledgments

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